July 2, 2020

VIA ELECTRONIC FILING
Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
Office of the Secretary
445 12th Street, SW
Washington, DC 20554

Re: *Written Ex Parte Submission,* GN Docket No. 18-122

Dear Ms. Dortch,

On behalf of the Aerospace Vehicle Systems Institute ("AVSI") project team, the attached report "Helicopter Air Ambulance RF Interference Scenario" ("HAA Interference Report") is provided to the Commission to assist it with ongoing work in GN Docket 18-122 to identify and address the potential for harmful interference from future flexible use operations to adjacent band aviation safety systems. The HAA Interference Report investigates helicopter air ambulance ("HAA") operations at the Texas Medical Center in Houston to determine the extent to which radio altimeter types commonly used on board helicopters will be subject to harmful interference from potential 5G emitters in real world operational scenarios. The study uses actual heliport locations, currently installed major carrier base stations locations, published 5G characteristics, and FCC-specified power limits to demonstrate that harmful interference to radar altimeters can be expected to occur from proposed flexible use systems. The situation at Texas Medical Center is believed to be illustrative of locations in urban areas throughout the country characterized by close proximity of helipads used for HAA and mobile service base stations. The HAA Interference Report concludes that careful examination of a wider range of interference scenarios is warranted to develop appropriate measures applicable to flexible use license deployments to mitigate the risk of harmful interference to the operation of aircraft.

AVSI is continuing its investigations to fully characterize the impact of out-of-band interference on radio altimeter performance, including testing additional altimeters and interference signals. AVSI is also coordinating with other multi-stakeholder efforts to analyze the potential for proposed wireless communication signals in the 3700 to 3980 MHz frequency range to impose harmful interference on radio altimeters that currently perform safety-of-life functions in all types of aircraft.

Respectfully submitted,

/s/ David Redman
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On behalf of the AVSI AFE 76s2 project team

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AFE 76s2 Report

Helicopter Air Ambulance RF Interference Scenario

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List of Acronyms

4G	fourth-generation mobile telephone
5G	fifth-generation mobile telephone
AC	[FAA] advisory circular
AFE	authority for expenditure
AGL	above ground level
ASRI	Aviation Spectrum Resources, Inc.
AVSI	Aerospace Vehicle Systems Institute
dB	decibel
dBi	decibel-isotropic
dBm	decibel-milliwatts
EIRP	effective isotropic radiated power
FAA	U.S. Federal Aviation Administration
FCC	U.S. Federal Communications Commission
GHz	gigahertz
HAA	helicopter air ambulance
HTAWS	helicopter terrain awareness warning system
IATA	International Air Transport Association
IMC	instrument meteorological conditions
ITU-R	International Telecommunication Union - Radiocommunication Sector
LTE	Long-Term Evolution
MHz	megahertz
MSL	mean sea level
NASA	U.S. National Aeronautics and Space Administration
OoBI	out-of-band interference
PSD	power spectral density
RA	radar altimeter
RF	radio frequency
RTCA	RTCA, Inc. – f/k/a the Radio Technical Commission for Aeronautics.
SC	special committee under RTCA, e.g. SC-239
TAMU	Texas A&M University

Executive Summary

The Aerospace Vehicle Systems Institute (AVSI) membership has investigated helicopter air ambulance (HAA) operations to determine whether radar altimeters on board helicopters will be subject to harmful interference from potential 5G emitters in real world operational scenarios. This study considers actual heliport locations relative to currently installed cellular base station locations. The study uses the available 5G characteristics and FCC specified power limits and finds that radar altimeters currently installed on HAA aircraft will be subject to harmful interference from 5G base stations under the real world scenarios examined.

AVSI is an aerospace industry research cooperative based at Texas A&M University (TAMU) that facilitates pre-competitive research projects among its members, which include organizations from the aerospace industry, related government agencies, and academia. This project (AFE 76s2) was organized under AVSI to empirically determine in a laboratory setting the characteristics of out-of-band interference that degrade radar altimeter performance. AVSI/TAMU provided a neutral, standard test setup that supported “black-box” testing of commercial radar altimeters, i.e. altimeters were tested without knowledge of proprietary features of the equipment by providing stimuli through the externally accessible receive port of the altimeter and while monitoring the reported altitude on the standard avionics bus output. This study was performed to compare measured interference power threshold values to out-of-band interference powers that could reasonably be expected in the real world operational scenarios described in this report.

Project members contributed material resources and technical expertise. Contributors to this project included Airbus, Aviation Spectrum Resources, Inc. (ASRI), Collins Aerospace, Embraer, U.S. Federal Aviation Administration (FAA), Garmin, Honeywell, International Air Transport Association (IATA), Lufthansa Technik, U.S. National Aeronautics and Space Administration (NASA), Safran, Texas A&M University, and Thales.

1 Introduction

1.1 Background

The Federal Communication Commission's (FCC) *Report and Order and Order of Proposed Modification* in the matter of Expanding Flexible Use of the 3.7 to 4.2 GHz Band grants a new spectrum allocation from 3.7 to 3.98 GHz for flexible use licenses within the band adjacent to that long used by radar altimeters (4.2-4.4 GHz), which will be utilized for 5G mobile wireless telecommunications systems.[1] During the FCC's rulemaking process, analysis and testing was conducted by AVSI to determine any potential compatibility or interference issues with this new allocation that may arise in commercially available, representative radar altimeters deployed in aircraft today.[2] These radar altimeters are inherently wideband and very sensitive RF systems that may be prone to harmful interference from strong emissions sources from outside of the 4.2 to 4.4 GHz band. Additional work is ongoing within RTCA[3] Special Committee 239 (SC-239).[4] to further evaluate the potential for any harmful interference to radar altimeters. SC-239 was set up as a multi-stakeholder group as encouraged by the FCC's *Report and Order* to address various compatibility and other technical issues pertaining to the new allocation prior to the spectrum target auction date in December 2020.

1.2 Interference Scenario Considerations

Much of the discussion of radar altimeters throughout these analysis efforts has focused on high-criticality approach and landing scenarios for fixed-wing commercial air transport aircraft, such as those used for passenger air travel. These particular scenarios present significant aviation safety impacts given the dependence upon the radar altimeter functionality during these phases of flight and the number of passengers which may be at risk. But the usage of radar altimeters on aircraft is much more far-reaching. Therefore, a thorough analysis of the potential for harmful interference from 5G systems must consider a wider range of scenarios, including not only other phases of flight on commercial air transport aircraft, but also operations of other types of aircraft.

Helicopters present a case which also merits close study of potential harmful interference from flexible use operations in the 3.7-4.2 GHz Band. Unlike most fixed-wing aircraft operations, the operation of helicopters at low altitudes (e.g. less than 6,000 feet above ground level (AGL)) at which radar altimeters may be susceptible to harmful interference from terrestrial emissions sources is not restricted to established or predefined flight paths. Therefore, harmful interference, to the extent it exists, cannot be wholly avoided simply by maintaining sufficient standoff distances between the emissions sources (e.g. 5G base stations) and airports or known flight paths for airplanes. This study focuses on the existence of that interference potential.

[1] *Expanding Flexible Use of the 3.7 to 4.2 GHz Band*, GN Docket No. 18-122, Report and Order and Order of Proposed Modification, 35 FCC Rcd 2343 (March 3, 2020) ("*Report and Order*").

[2] *See* "Behavior of Radio Altimeters Subject to Out-Of-Band Interference," attachment to Letter of Dr. David Redman, AVSI, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 (Oct 22, 2019) ("AVSI Preliminary Report"); *see also* "Effect of Out-of-Band Interference Signals on Radio Altimeters," attachment to Letter of Dr. David Redman, AVSI, to Marlene H. Dortch, Secretary, Federal Communications Commission, GN Docket No. 18-122 (Feb. 4, 2020) ("AVSI Supplemental Report").

[3] The Radio Technical Commission for Aeronautics, now referred to simply as "RTCA".

[4] *See* https://www.rtca.org/content/sc-239 for more information.

This study expands a preliminary study that investigated potential interference from a single base station on radar-equipped aircraft following a fixed landing approach, which is applicable to fixed-wing and helicopter operations.[5]

1.3 Helicopter Air Ambulance Operations

Most commercial operations of helicopters fall under Part 135 of the Federal Aviation Regulations, which explicitly requires the use of a Federal Aviation Administration (FAA) approved radar altimeter.[6] The FAA explained their reasoning for this requirement as follows:

> *[r]adio altimeters can greatly improve a pilot's awareness of height above the ground during hover, landing in unimproved landing zones, and landings in confined areas where a more vertical approach may be required. Additionally, radio altimeters help increase situational awareness during inadvertent flight into instrument meteorological conditions (IMC), night operations, and flat-light, whiteout, and brownout conditions.*[7]

Included under the umbrella of Part 135 are helicopter air ambulance (HAA) operations. For HAA operations, FAA rules further require the use of a Helicopter Terrain Awareness Warning System (HTAWS),[8] which will often utilize the output from the radar altimeter and GPS to alert the pilot when flying dangerously close to terrain or other obstacles.

Safe operation of HAA services requires proper functionality of radar altimeters. This study examines a few particular real-world scenarios at specific, illustrative locations for HAA aircraft and describes the potential for harmful interference from 5G systems operating in accordance with the FCC *Report and Order*.

2 Scenario Description

2.1 Overview

The Texas Medical Center in Houston is the world's largest medical complex,[9] containing a total of 54 medical institutions, including 21 hospitals, within a two-square-mile area. Many of these hospitals include rooftop heliports, from which HAA aircraft are dispatched and to which HAA aircraft ferry trauma patients and others who need immediate medical attention. Further, mobile wireless base stations are located throughout the complex to provide connectivity to the masses of employees, patients, and visitors of the medical institutions in the dense urban setting.

Four heliports within the complex were reviewed, and likely approach flight paths were defined relative to each. Further, two currently used mobile wireless base station antenna locations were identified for use in the study. Along each of the four flight paths, the interference levels seen by the radar altimeter on the HAA aircraft were calculated assuming that each base station was hypothetically upgraded to a 5G system operating in accordance with the parameters specified within the FCC *Report and Order* in

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[5] *See* Letter of Edward A. Yorkgitis, Jr., Kelley Drye & Warren LLP, Counsel to ASRI, to Marlene H. Dortch, Secretary, Federal Communications Commission, Notice of Ex parte Meeting, GN Docket No. 18-122, at 12-13 (Feb. 19, 2020; Corrected Copy filed Feb. 20, 2020); see also id., Attachment A, at 9-12 & Attachment B, at 1-4.

[6] 14 C.F.R. § 135.160.

[7] *See* FAA, *Helicopter Air Ambulance, Commercial Helicopter, and Part 91 Helicopter Operations*, 79 Fed. Reg. 35, at 9933, table 1 (Feb. 21, 2014).

[8] 14 C.F.R. § 135.605.

[9] *See* https://www.tmc.edu/wp-content/uploads/2016/08/TMC_FactsFiguresOnePager_0307162.pdf.

the 3.7-3.98 GHz band.[10] These levels were then compared to the empirical interference tolerance thresholds measured by AVSI for a number of altimeter models which are commonly used in HAA aircraft.

Figure 1 illustrates the basic geometry of the scenario, with the heliport locations indicated by red markers, the flight paths indicated by red lines with green surfaces projected to the ground, and the base station locations indicated by blue markers:

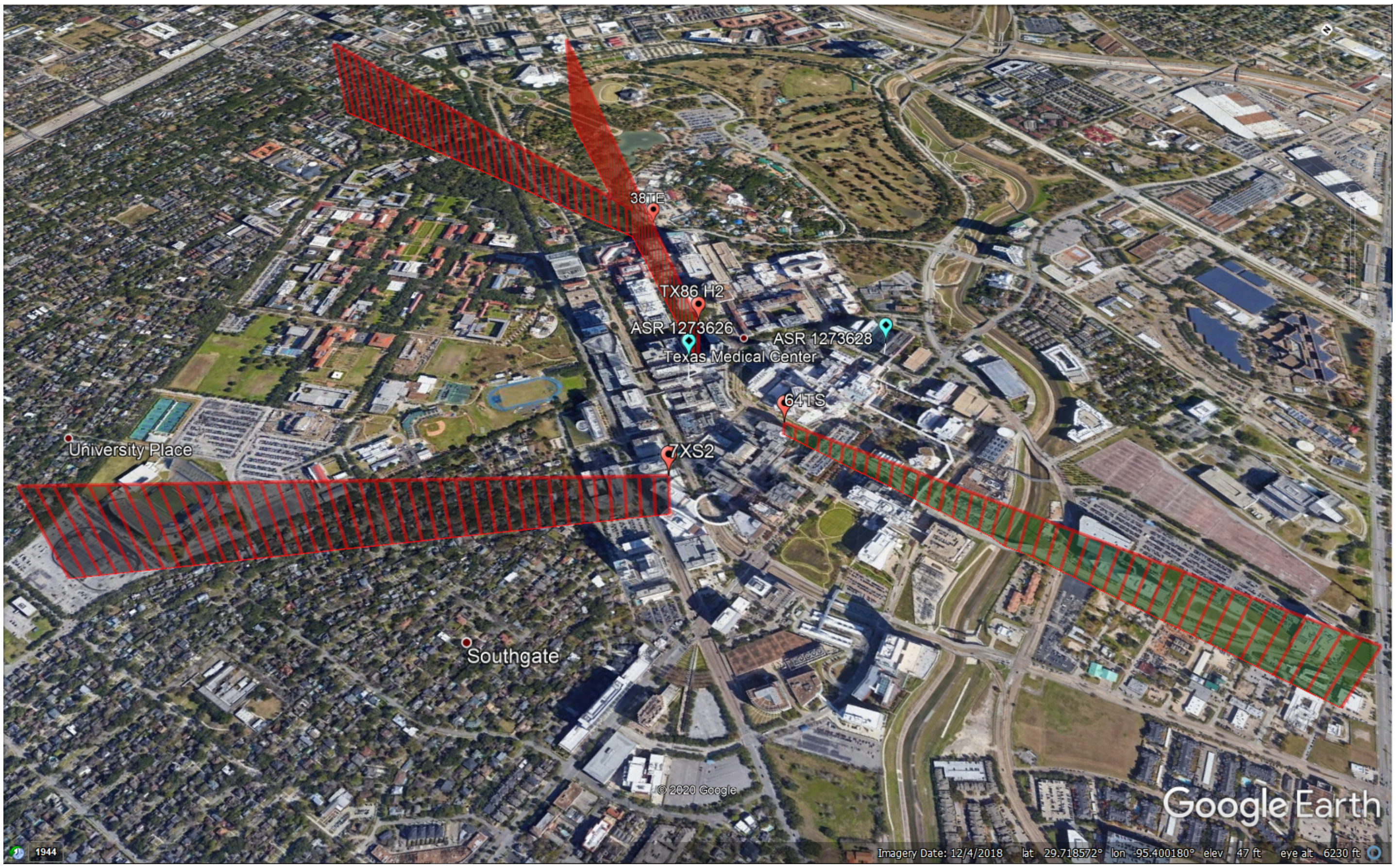

Figure 1: Map of Texas Medical Center

2.2 Heliport Locations

The four heliports used in the analysis were the John S Dunn Heliport (FAA identifier 38TE) at Memorial Hermann Hospital, the Alkek Heliport (FAA identifier TX86) at Houston Methodist Hospital, the Baylor St. Luke's Medical Center Heliport (FAA identifier 64TS), and the Texas Children's Hospital Downtown Heliport (FAA identifier 7XS2). The locations of each of these heliports is listed in Table 1. All data is sourced from AirNav.com[11] and Google Earth[12].

[10] The aviation community has only recently received a response from the commercial wireless community on specific questions for their proposed usage of the 3.7-3.98 GHz band, which will be incorporated into further studies.

[11] http://airnav.com/airports/

[12] Map showing location of Texas Medical Center. *Google Earth*, https://earth.google.com/web/.

Table 1: Heliport Characteristics

#	Hospital Name	FAA ID	Latitude	Longitude	Elevation (MSL)	Height (AGL)
1	Memorial Hermann	38TE	29° 42’ 48” N	95° 23’ 41” W	303 ft	255 ft
2	Houston Methodist	TX86	29° 42’ 38” N	95° 23’ 55” W	445 ft	400 ft
3	Baylor St. Luke’s	64TS	29° 42’ 28” N	95° 23’ 57” W	165 ft	120 ft
4	Texas Children’s	7XS2	29° 42’ 29” N	95° 24’ 10” W	427 ft	385 ft

2.3 Flight Paths

The approach paths flown into hospital heliports may vary depending on the situation and the presence of any surrounding obstacles (e.g. other buildings). However, to define flight paths for this interference analysis scenario, a standard 8:1 approach/departure surface was assumed in accordance with FAA Advisory Circular (AC) 150/5390-2C on Heliport Design.[13] That is, each flight path is defined as a straight line between the heliport location itself and a point in space which is at a horizontal distance of 4,000 ft from the heliport and at an elevation 500 ft higher than the heliport. The azimuthal direction in which this line was drawn from each heliport was based upon a preferred approach direction determined by observing the heliport markings in Google Earth and reviewing any relevant remarks on AirNav.com for each heliport. While selection of the flight paths was not dependent on the relative position of the base stations, it should be noted that the flight paths maintain separation from the base station installations.

2.4 5G Base Station Locations

As previously mentioned, the assumed locations of 5G base stations in the interference scenario were set based on the locations of existing 4G LTE base stations in the vicinity of the heliports. This was done using CellMapper.net to initially determine approximate locations of candidate base stations, and then verifying the exact locations using the FCC Antenna Structure Registration database.[14] Finally, the base stations were further identified visually using Google Earth imagery.

Two base stations were identified for consideration in the scenario. The locations of these base stations are given in Table 2. The first base station listed in the table is located on a parking structure, and the second base station is located on top of the Fondren/Brown/Alkek building at Houston Methodist Hospital (just one building over from the Alkek Heliport).

Table 2: LTE Base Station Characteristics

FCC Registration	Latitude	Longitude	Elevation (MSL)	Height (AGL)
1273628	29° 42’ 26” N	95° 23’ 42” W	155 ft	110 ft
1273626	29° 42’ 37” N	95° 23’ 58” W	271 ft	225 ft

Table 3 shows the distance from each LTE base station to each heliport.

[13] *See* FAA, AC 150/5390-2C, *Heliport Design* (April 24, 2012) Chapter 4 on Hospital Heliports, and Figure 4-6 illustrating the approach/departure surface.

[14] https://wireless2.fcc.gov/UlsApp/AsrSearch/asrRegistrationSearch.jsp

Table 3: Distance from LTE Base Station to Heliport

FCC Registration	Distance			
	Memorial Hermann (38TE)	Houston Methodist (TX86)	Baylor St. Luke's (64TS)	Texas Children's (7XS2)
1273628	2203 ft	1722 ft	1465 ft	2516 ft
1273626	1819 ft	164 ft	964 ft	1351 ft

3 Interference Model and Assumptions

3.1 Propagation Model

This analysis conservatively considers direct line-of-sight propagation from the base station to the radar altimeter receive antenna only. A more thorough analysis would also consider additional coupling paths via signal reflections from buildings or other surfaces, which could potentially lead to higher levels of interference received by the radar altimeter if any reflected signals are directed into the main lobe of the receive antenna.

3.2 Aircraft Assumptions

For simplicity, this analysis assumes the helicopters had a single radar altimeter installed and were flown in level attitude at all times during the approach. That is, the pitch and roll angles are both assumed to be zero throughout the full flight path.

3.3 Radar Altimeter Assumptions

The radar altimeter receive antenna pattern was calculated using the method outlined in Report ITU-R M.2319-0, Annex 3,[15] assuming a 10 dBi boresight gain and a 60° full half-power beamwidth (i.e. ±30° from boresight).[16] Further, 3 dB of coaxial cable loss was assumed between the receive antenna and the altimeter receiver input. These assumptions are consistent with those made by AVSI in previous testing and analysis, allowing for the most direct comparison with previously measured interference tolerance thresholds.

3.4 Base Station Assumptions

The analyses examined the impact of single base stations of up to 100 MHz bandwidth each. Aggregate effects were not examined. Each base station antenna radiation pattern was assumed to be uniform in the azimuth plane. In the elevation plane, the radiation pattern was calculated in accordance with Recommendation ITU-R F.1336-5,[17] assuming a 7° elevation beamwidth and 3° downtilt. Further, each

[15] *See* ITU-R Report M.2319-0, *Compatibility analysis between wireless avionic intra-communication systems and systems in the existing services in the frequency band 4 200-4 400 MHz*, (November 2014), Equation A-3.6 at 28.

[16] An accurate characterization of antenna frequency dependent rejection (FDR) was not available for use in this study, however preliminary information indicates that the contribution of antenna FDR to out-of-band signal rejection will be minimal for the conditions in this study. Such characterization is being pursued as quickly as possible and data will be made available for future study.

[17] ITU-R Report F.1336-5, *Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile services for use in sharing studies in the frequency range from 400 MHz to about 70 GHz*, (January 2019).

base station was assumed to be emitting at the maximum limits specified for urban environments in the FCC *Report and Order*, which is 1640 W/MHz (62 dBm/MHz) EIRP for non-rural implementations.[18]

The first base station (located on the parking structure) is assumed to have a downlink center frequency of 3750 MHz, and the second base station (located on the Fondren/Brown/Alkek building) is assumed to have a downlink center frequency of 3850 MHz, allowing for up to 100 MHz of bandwidth for each.[19]

4 Analysis Results

4.1 Heliport #1: Memorial Hermann Hospital

Figure 2 shows the computed power spectral density (PSD) at the radar altimeter receive port due to interference from each base station throughout the approach scenario for the John S Dunn Heliport at Memorial Hermann Hospital:

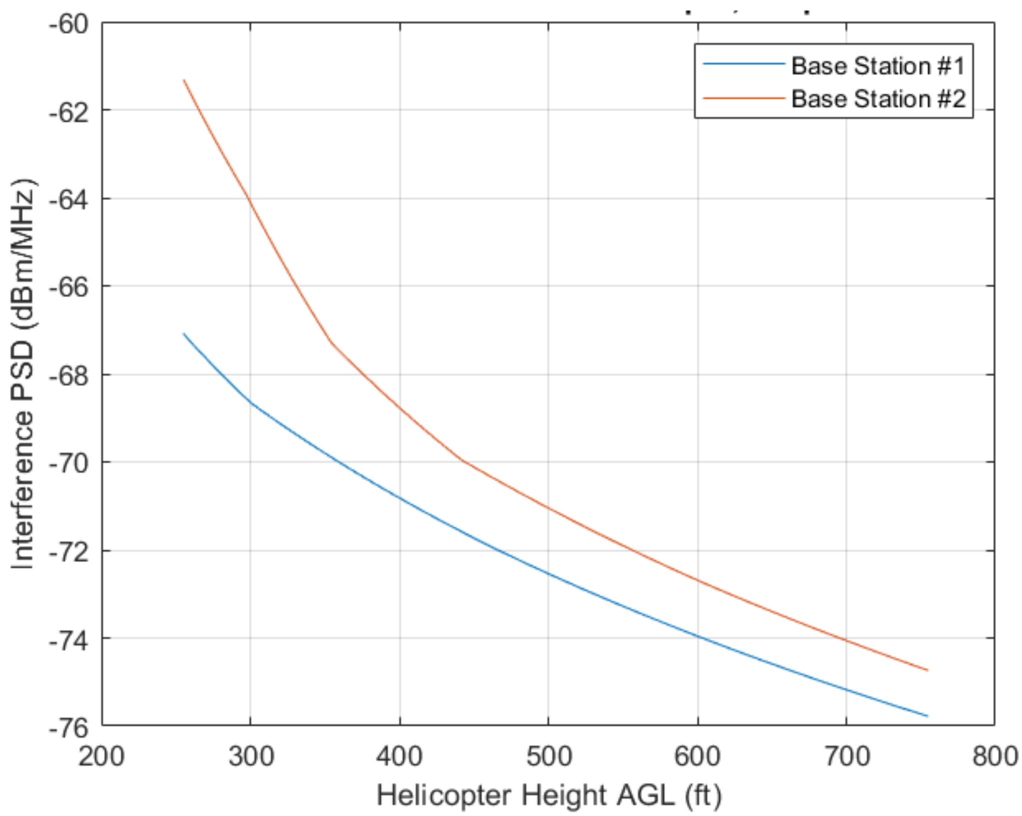

Figure 2: Computed Interference at Radar Altimeter Receiver Input for Heliport #1

The maximum interference PSD for Base Station #1 is -67 dBm/MHz at 255 ft AGL. The maximum interference PSD for Base Station #2 is -61.3 dBm/MHz at 255 ft AGL.

[18] *Report and Order,* Appendix A “Adopted Rules” at 9 adding 47 C.F.R. § 27.50(j)(2).

[19] Note that while the base stations are assumed to be operating at offset frequencies to represent more realistic network deployments, this analysis does not consider aggregate interference, but considers each base station individually.

4.2 Heliport #2: Houston Methodist Hospital

Figure 3 shows the computed PSD at the radar altimeter receive port due to interference from each base station throughout the approach scenario for the Alkek Heliport at Houston Methodist Hospital:

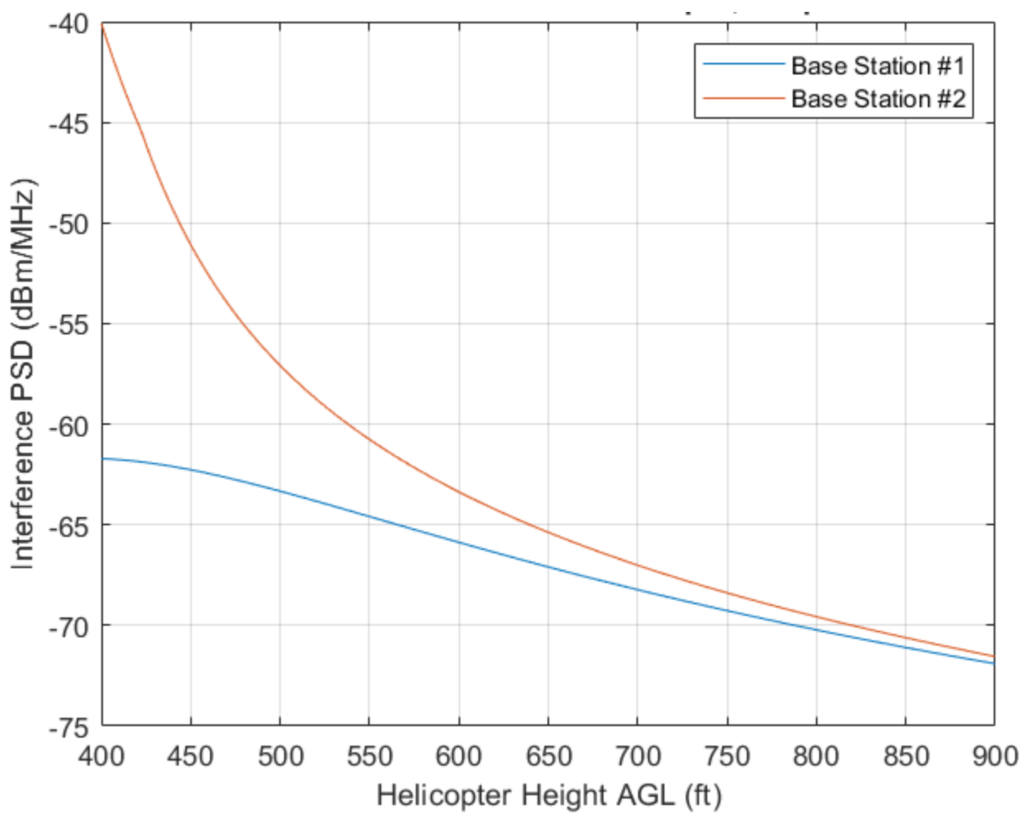

Figure 3: Computed Interference at Radar Altimeter Receiver Input for Heliport #2

The maximum interference PSD for Base Station #1 is -62 dBm/MHz at 400 ft AGL. The maximum interference PSD for Base Station #2 is -40 dBm/MHz at 400 ft AGL.

4.3 Heliport #3: Baylor St. Luke's Medical Center

Figure 4 shows the computed PSD at the radar altimeter receive port due to interference from each base station throughout the approach scenario for the Baylor St. Luke's Medical Center Heliport:

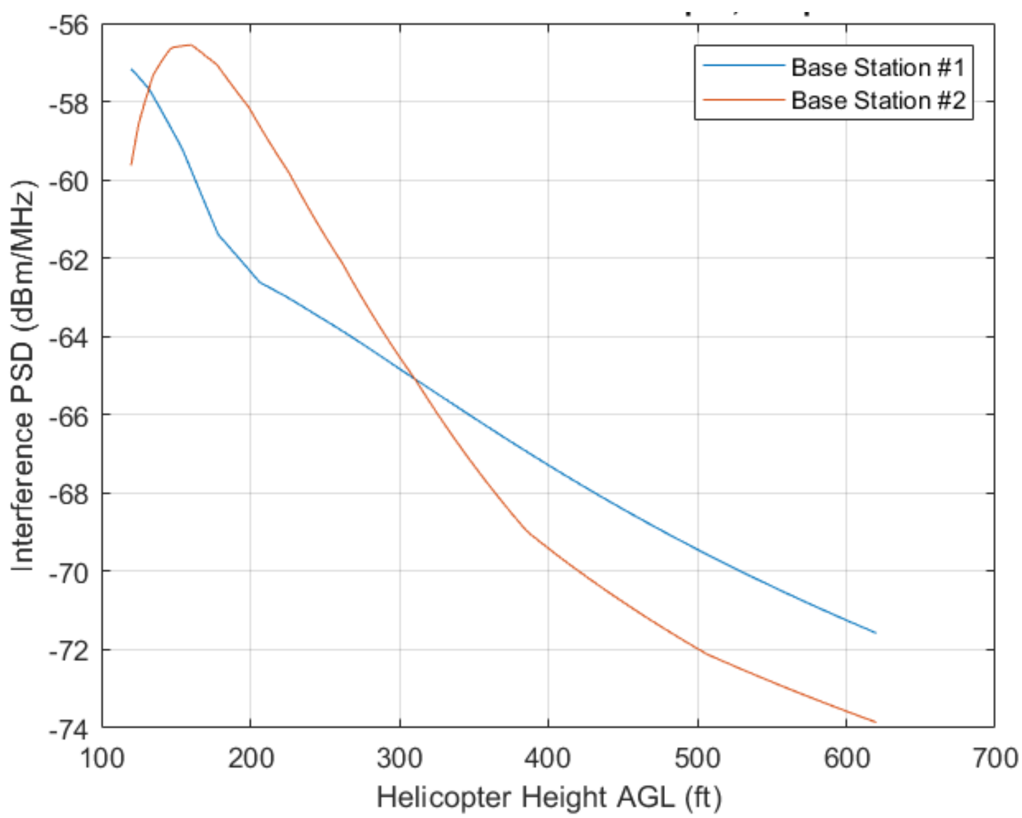

Figure 4: Computed Interference at Radar Altimeter Receiver Input for Heliport #3

The maximum interference PSD for Base Station #1 is -57 dBm/MHz at 120 ft AGL. The maximum interference PSD for Base Station #2 is -56.5 dBm/MHz at 160 ft AGL.

4.4 Heliport #4: Texas Children's Hospital

Figure 5 shows the computed PSD at the radar altimeter receive port due to interference from each base station throughout the approach scenario for the Texas Children's Hospital Downtown Heliport:

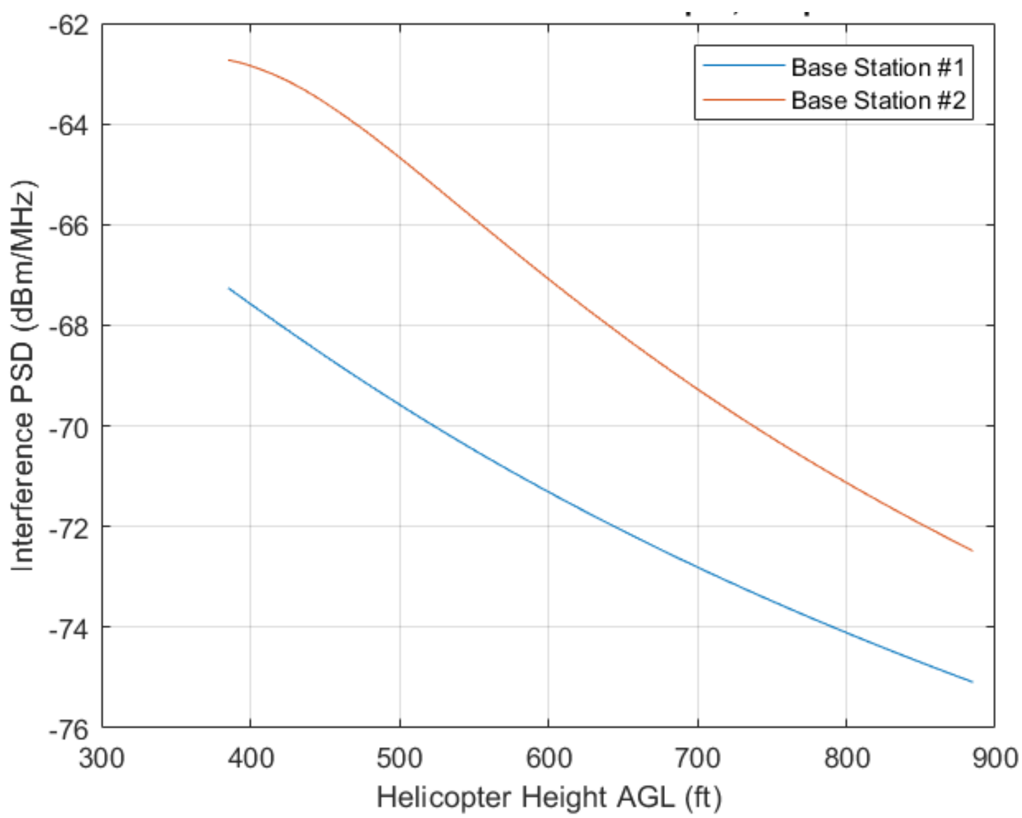

Figure 5: Computed Interference at Radar Altimeter Receiver Input for Heliport #4

The maximum interference PSD for Base Station #1 is -67.2 dBm/MHz at 385 ft AGL. The maximum interference PSD for Base Station #2 is -62.5 dBm/MHz at 385 ft AGL.

5 Discussion of Results

Two of the seven radar altimeter models previously tested by AVSI, Type 6 and Type 7, are known to be commonly used on helicopters for HAA operations.[20] Of these, the Type 6 has a measured interference tolerance threshold of -20 dBm/MHz for 100 MHz-wide OFDM interference signals centered at either 3750 or 3850 MHz with the altimeter operating at 200 feet AGL.[21]. Type 7 has an interference tolerance threshold of -47 dBm/MHz under the same conditions. Table 4 summarized the maximum interference PSD (PSD_i) for each base station and heliport, along with the interference tolerance threshold (P_{ITT}) for the Type 6 and Type 7 altimeters.

Table 4: Maximum PSD Relative to Interference Tolerance Threshold for Type 6 & 7 Altimeters

#	Hospital Name	Max PSD_i from BS #1	Max PSD_i from BS #2	P_{ITT} Type 6 Altimeter	P_{ITT} Type 7 Altimeter	Units
1	Memorial Hermann	-67	-61.3	-20	-47	dBm/MHz
2	Houston Methodist	-62	-40	-20	**-47**	dBm/MHz
3	Baylor St. Luke's	-57	-56.5	-20	-47	dBm/MHz
4	Texas Children's	-67.2	-62.5	-20	-47	dBm/MHz

Table 4 demonstrates that 5G systems operating in accordance with the FCC *Report and Order* in the 3.7-3.98 GHz band under this scenario would exceed the interference tolerance threshold for helicopters equipped with Type 7 altimeters, which indicates that further analysis is warranted to fully characterize additional aircraft operational scenarios.

[20] *See* note 2, *supra*.

[21] Note that 200 ft is the closest test altitude for which AVSI data is available for comparison to the heliport AGLs considered in this study.

6 Conclusion

This analysis demonstrates that harmful interference to radar altimeters in common use today will in fact occur from 5G systems operating in accordance with the FCC *Report and Order* in the 3.7-3.98 GHz band under the real-world operational scenarios considered herein. The situation at Texas Medical Center is believed to be illustrative of locations in urban areas throughout the country characterized by close proximity of helipads used for HAA and mobile service base stations. Furthermore, the Type 7 altimeter is known to be widely deployed in the helicopter market and sees substantial usage with a large installation base up to the present day. These results underscore the need for careful examination of a wider range of interference scenarios in order to develop appropriate measures applicable to flexible use license deployments to mitigate the risk of harmful interference to the operation of aircraft.

Additional testing is currently underway at AVSI that will consider two additional altimeter models which have not previously been tested in the AFE 76s2 project, both of which are also commonly used in helicopters. The additional data, which will be submitted into the Commission's record, will provide further insight into the potential impact to HAA operations from flexible use operations. Additionally, further information regarding the 5G base station characteristics, appropriate safety margin allocations and aggregate effects, as well as helicopter pitch and roll effects may be used to augment this study.